Post-Lamination Manufacturing Process Automation for Photovoltaic Modules

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ABSTRACT

New automated systems are being developed at Spire Corporation for photovoltaic module manufacturing, under the National Renewable Energy Laboratory's Photovoltaic Manufacturing Technology (PVMaT) project. These systems address the module assembly and testing processes done after lamination, including edge trimming, edge sealing, framing, junction box installation, and testing. The systems are designed to process both thin-film and crystalline-cell modules.

Currently, module manufacturers use little or no automation for the assembly tasks performed after lamination. As the PV industry grows and production levels increase, the use of automated systems will reduce labor costs, improve product quality, and increase throughput. In addition, repetitive stress injuries may be avoided by eliminating manual product lifting and edge trimming operations.

1. Introduction

Full-scale prototype production systems are being developed for processing modules up to 102 cm by 162 cm. Five automated systems are under development: a laminate edge trimmer, a laminate edge sealer/framer, a junction box installer, a module performance and safety tester, and a module storage buffer. Three of these, the trimmer, tester, and buffer, were recently designed, fabricated, and demonstrated. The two remaining systems, the edge sealer/framer and the junction box installer, are now in the design and build phase. Once complete, these systems may be combined to form an automated module assembly and testing line. The throughput goal is one module per minute, equivalent to 9.3 MW/year of 75 W modules on a one-shift (40 hour/week) basis.

All of the systems are designed with motor-driven roller conveyors for automated material loading and unloading, and incorporate a standard handshake protocol for passing product from one process to the next [1]. Each system has a two-axis aligner to position the laminate or module for processing.

2. Laminate Edge Trimming

The laminate edge trimming system, shown in Figure 1, removes excess encapsulant and back sheet material from the edges of a module after lamination. The module is aligned, transported into the trimming system, and lifted above the conveyor to provide access to the module edges. Two fiber optic sensors mounted on a four-axis Cartesian robot locate the glass edges by scanning across each corner of the module. Robot position data is captured when the sensors see a change in reflectance at the glass edges. This data determines the path of a hot knife, also mounted on the robot arm, which trims the excess material around the perimeter of the module.

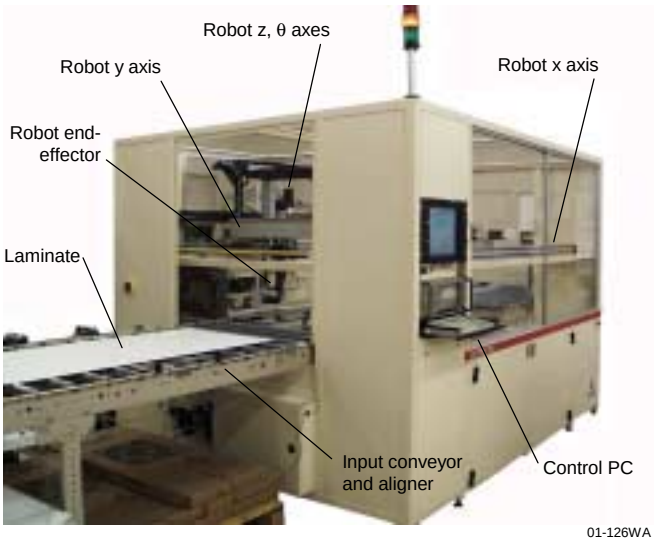

Fig 1. SPI-TRIM™ 350 module edge trimmer.

3. Module Edge Sealing and Framing

The module edge sealer/framer installs frames on trimmed module laminates, using corner keys to fasten the frame sections together and hot-melt sealant to provide a cushion and adhesion between the module glass sheet and the metal frame. The system is shown during assembly in Figure 2.

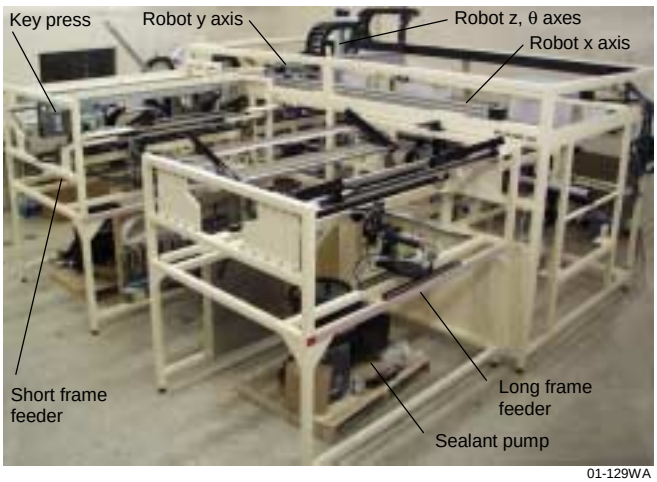

Fig 2. SPI-FRAME™ 350 module edge sealer and framer during assembly. The frame press and robot end-effector are located in the main section at rear.

A module aligner and lift system, similar to those used in the edge trimmer, position a module laminate in a two-axis frame press above a conveyor. Frame feeders dispense long and short frame sections from stacks and place them on a carriage. Corner key feeders dispense L-shaped keys that are automatically pressed into both ends of the short frame sections. Sealant dispensers inject hot melt sealant into a channel in each frame section as the sections are driven past the dispensers by the carriage. A four-axis Cartesian robot with mechanical grippers picks up two frame sections from each frame carriage and transports them to the frame press. The frame press immediately pushes the frame sections onto the edges of a module laminate before the sealant cools. The corner keys in the short frame sections are driven into the long sections to make a mechanically solid frame connection.

4. Junction Box Installation

The junction box installer uses a flexible workstation approach to handle a variety of tasks required to attach and seal a junction box to a module's back surface. The design is shown in Figure 3. A four-axis SCARA robot with a tool changer selects from three different end-effectors (tools) to lift and bend metal ribbon output leads to an upright position, clean the junction box area with alcohol, dispense sealant in a pattern to match the junction box, and place a junction box with controlled force on the sealant.

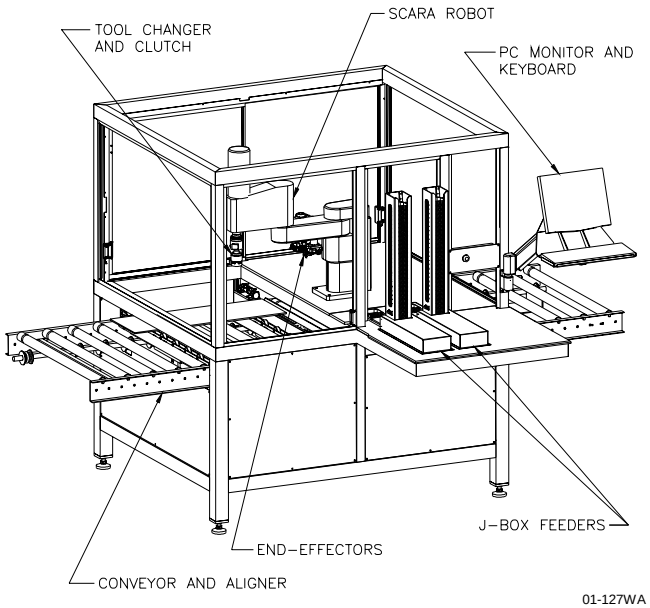

Fig 3. SPI-BOXER^{TM} 350 junction box installer.

Two junction box feeders dispense boxes from stacks to nests for pick up by the robot. Silicone sealant is pumped from a 19-liter pail through a tethered line to a dispensing valve and nozzle on the end-effector.

5. Module Performance and Safety Testing

The module tester performs an electrical isolation (hi-pot) test, a ground continuity test, and an electrical performance test (I-V measurement with a solar simulator). The equipment, shown in Figure 4, also includes automation for transporting, aligning, and probing modules. Detailed results of tester evaluations were reported previously [2]. A production rate of 52 seconds per module was achieved, equivalent to 9.7 MW of 75 W modules per year on a single shift basis.

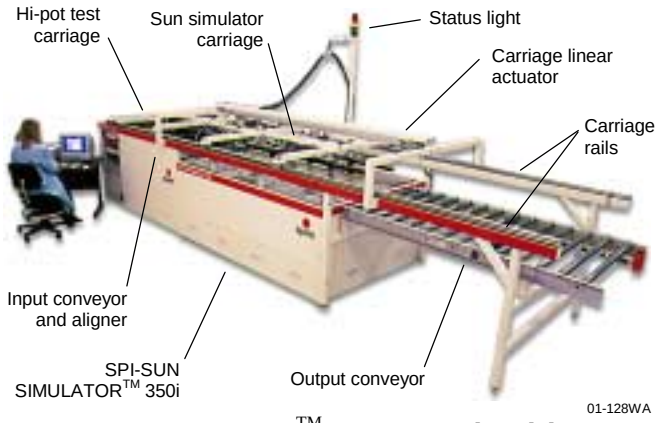

Fig 4. SPI-MODULE QA^{TM} 350 integrated module tester.

6. Module Buffering

The module storage buffer system, shown in Figure 5, uses a pivoting vacuum pick-up arm to transfer laminates or modules between a conveyor and a cart. The system can feed modules from the cart, store them temporarily between processes, or accumulate them after processing.

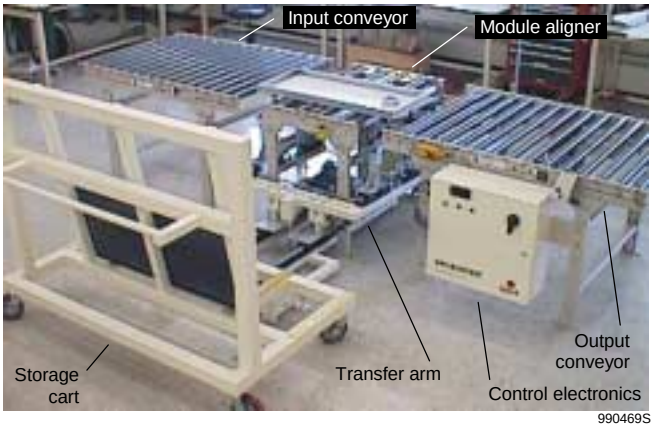

Fig 5. SPI-BUFFER^{TM} 350 buffer storage system.

7. Acknowledgment

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REFERENCES

[1] SMEMA Interface Standard 1.2, Surface Mount Equipment Manufacturers Association, Lafayette Hill, PA (1993).

[2] M. Nowlan, J. Sutherland, E. Lewis, and S. Hogan, "Evaluations of an Automated Photovoltaic Module Test System," proc. 16th European Photovoltaic Solar Energy Conf., Glasgow, UK, May 1-5, 2000.